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Signed M Cunkie

Dated 27 August 2004

Patents Form 1/77

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19AUG03 E831235-2 D01631
P01/7700 0.00-0319389.3

1/77

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form.)

The Patent Office

Cardiff Road
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Gwent NP9 1RH

Fee: £0

1. Your reference

   IML/kz/45791.GB03

2. Patent application number
   (The Patent Office will fill in this part)

   0319389.3

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   E2V TECHNOLOGIES LIMITED
   106 WATERHOUSE LANE
   CHELMSFORD
   ESSEX, CM1 2QU

   Patents ADP number *(if you know it)*

   8457749001

   If the applicant is a corporate body, give the country/state of incorporation

   UNITED KINGDOM

4. Title of the invention

   MAGNETRONS

5. Full name, address and postcode in the United Kingdom to which all correspondence relating to this form and translation should be sent

   Reddie & Grose
   16 Theobalds Road
   LONDON
   WC1X 8PL

   Patents ADP number *(if you know it)*

   91001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application *(If you know it)*	Date of filing *(day/month/year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day/month/year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
   c) any named applicant is a corporate body.
   See note (d))

   YES

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document.

Continuation sheets of this form	
Description	04
Claim*(s)*	-
Abstract	-
Drawing*(s)*	01

8 ✓

10. If you are also filing any of the following, state how many against each item.

Priority documents	-
Translations of priority documents	-
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-
Request for preliminary examination and search *(Patents Form 9/77)*	-
Request for substantive examination *(Patents Form 10/77)*	-
Any other documents *(please specify)*	-

11. I/We request the grant of a patent on the basis of this application.

Signature Date

18 August 2003

12. Name and daytime telephone number of person to contact in the United Kingdom

I M LOVELESS
(020) 7242 0901

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After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

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MAGNETRONS

This invention is a means of phase-locking a rising-sun anode magnetron by injecting a TEM electromagnetic wave (at or near the operating frequency), into the coaxial interaction region between the magnetron anode and cathode. This is done by lengthening the cathode with a probe, which extends into a waveguide as shown in the figure. The vacuum is contained by a dielectric window. The TEM wave is excited by feeding a TE01 wave into the waveguide and adjusting the plunger for maximum radial electric field in the anode/cathode region.

The figure shows the arrangement for a single magnetron. A number of magnetrons could be locked in the required relative phases by fitting them into the waveguide at the appropriate distances along the waveguide.

Phase Control of Magnetrons using a Novel Phase Locking Technique

The need for improved phase locking

The Magnetron is a compact and efficient source of microwave power. These advantages have resulted in numerous attempts in the past to develop methods of phase locking magnetron oscillators so that they can replace large and less efficient amplifiers in many applications. All these attempts have been unsuccessful because the locking power required has been high, about 10 to 12 db below the output power of the magnetron.

The novel concept

All previous methods have been based on injecting the locking signal into the Magnetron cavities, either through the output connector or through an additional coupling system. The novel concept, for which invention is claimed, is to inject the locking signal directly into the anode cathode volume. In technical terms, a TEM wave is injected into the coaxial line formed by the anode and cathode. Magnetron designers would have considered this to be ineffective because where a magnetron is oscillating in the desired Pi mode, there is no net radial electric field in the volume between the anode and cathode so that there can be no coupling between the injected TEM mode and the Pi mode on the anode. This is correct reasoning so the concept has never previously been tried. It is well known that the 'rising sun' anode Magnetron design, which has alternate large and small cavities, has a zero order mode in the anode/cathode volume when it is oscillating in the Pi mode. This mode has a uniform RF current circulating round the anode vane surfaces and a corresponding RF axial magnetic field at the Pi mode frequency. The inventors speculated that although this mode would not couple directly to a TEM mode in the anode cathode volume, coupling might occur when space charge was present near the cathode. This was because the space charge would be perturbed by the radial electric field of the TEM wave of the injection frequency when the electron velocities were low and there would be a perturbed circulating current producing an RF axial magnetic field that would couple to the zero order component of the Pi mode of the 'rising sun' anode. If the injection frequency were close to the Pi mode frequency then, as the magnetron started to oscillate it, would lock to the injection signal. The question was the magnitude of the locking signal required for sustaining locking throughout the pulse.

Confirmation of the concept and quantitative assessment of the magnitude of the locking signal

The magnetron chose for investigation was a high power 10 cavity 'rising sun' anode magnetron operation in the region of 1.1 GHz.

Typical operating conditions:

Anode Voltage V_{DC} (kV)	Anode Current (A)	P_{out} (MW)	Frequency (GHz)
170	8.18	695.3	1.13
180	11.86	1067.4	1.129

With no anode voltage applied (i.e. no space charge) and injection voltages of $V_{DC}/10$, $V_{DC}/5$, $V_{DC}/3$ only noise was generated in the anode cavities. With anode voltage applied and no injected signal, oscillation started in about 10nS.

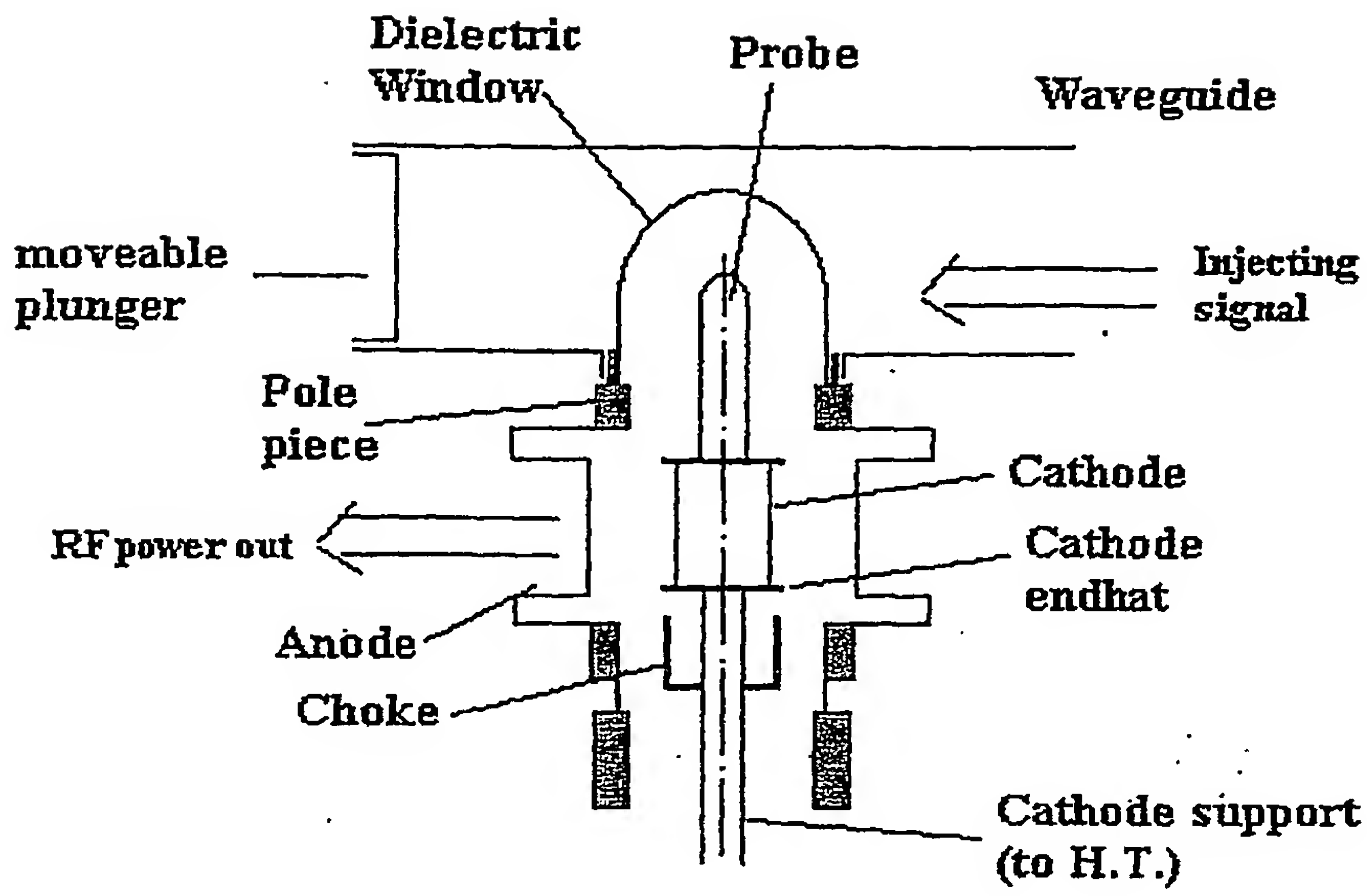
When a signal of $V_{DC}/10$ at the Pi mode frequency was injected, oscillation started immediately the voltage was applied. The output signal was compared with the injected signal and it remained locked in phase for 550nS, the duration of the applied pulse. If one assumes that the injected signal were completely absorbed at the cathode support end, the injected power would be $(V_{DC}/10)^2/2*Zo$ where Zo is the anode/cathode coaxial line impedance. This would be about 40Ω so that the input powers would be as follows:

Anode Voltage V_{DC} (kV)	P_{inj} (MW)	Ratio of P_{out} / P_{inj}	Gain (db)
170	3.61	192.6	22.8
180	4.05	263.6	24.2

However, this is the most pessimistic assessment. With a choke of the cathode support end the injected signal would be reflected and the input power would be much lower. A directional coupler would be necessary in the injection signal waveguide to prevent the reflected signal returning to the signal generator.

The embodiment of the invention

This is the critical part of the patent. With a high power magnetron the cathode lead will be at high voltage. It would therefore be completely impractical to inject an RF signal into the anode/cathode volume through the cathode support. The embodiment 1 is the important inventive step. The cathode is extended into a dielectric window and inserted into a waveguide as shown schematically in the figure below.



Embodiment 1: This is for a single-phase locked magnetron.

Embodiment 2: For a number of magnetrons, feeding a linear accelerator for example, the moveable plunger would be removed and the magnetrons would be spaced at intervals along the waveguide, which would be terminated by a matched load.

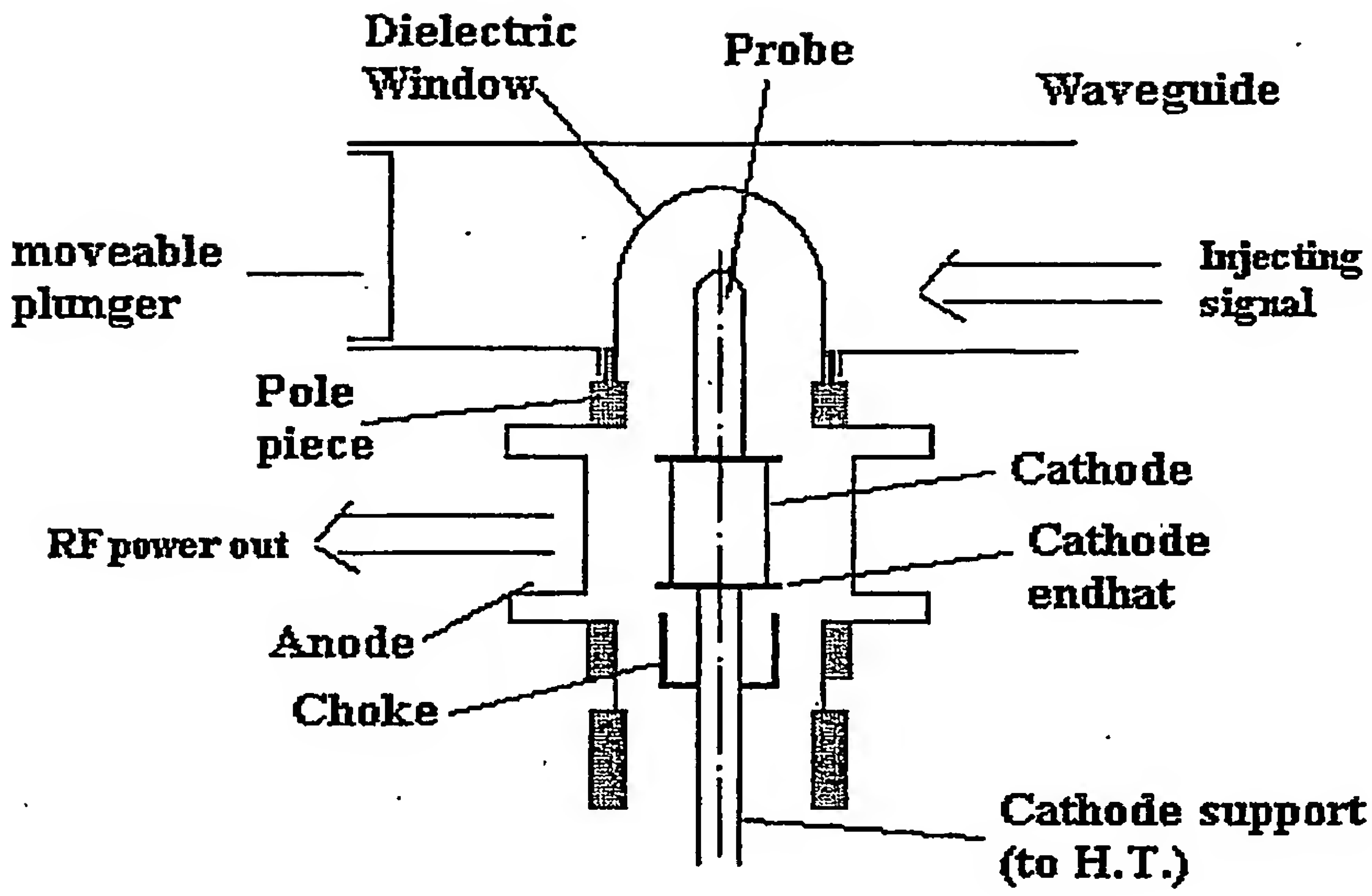
Embodiment 3: To prevent reflected RF power being returned to the signal source, it may be an advantage to have directional couplers in the waveguide before each magnetron.

Embodiment 4: The phase locking signal may be required to run continuously. This would then be a low power source locking a single pulsed magnetron, which would then drive an array of pulsed magnetrons.

Glossary

P_{inj} = Injected RF Power.

P_{out} = Magnetron RF Output Power.



Proposed Arrangement for Injecting a Locking Signal into the Interaction Space of a Magnetron (diagrammatic only)